NOAA TECHNICAL MEMORANDUM NMFS-SEFSC-447

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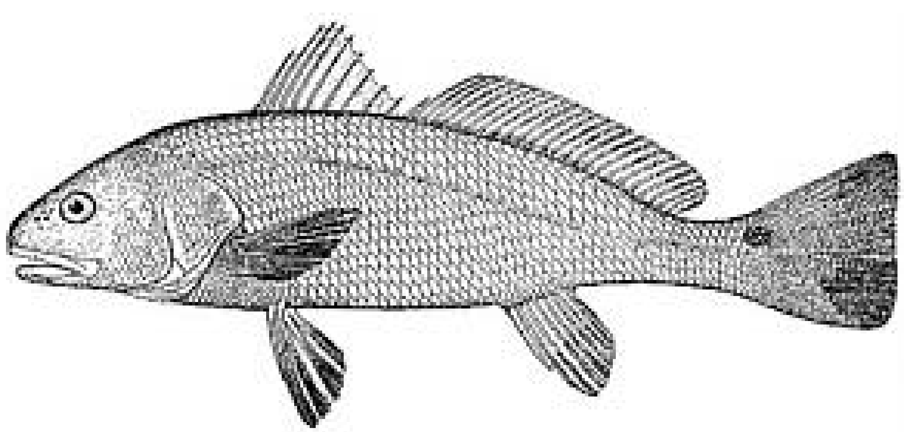

December 2000

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road
Beaufort, NC 28516-9722

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NOTICE

Correct citation of this report is:

Vaughan, D. S., and J. T. Carmichael. 2000. Assessment of Atlantic red drum for 1999: Northern and southern regions. NOAA Technical Memorandum NMFS-SEFSC-447.

Copies of this report can be obtained from:

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EXECUTIVE SUMMARY

An assessment of the status of the Atlantic stock of red drum is conducted using recreational and commercial data from 1986 through 1998. This assessment updates data and analyses from the 1989, 1991, 1992 and 1995 stock assessments on Atlantic coast red drum (Vaughan and Helser, 1990; Vaughan 1992; 1993; 1996). Since 1981, coastwide recreational catches ranged between 762,300 pounds in 1980 and 2,623,900 pounds in 1984, while commercial landings ranged between 60,900 pounds in 1997 and 422,500 pounds in 1984. In weight of fish caught, Atlantic red drum constitute predominantly a recreational fishery (ranging between 85 and 95% during the 1990s). Commercially, red drum continue to be harvested as part of mixed species fisheries.

Using available length-frequency distributions and age-length keys, recreational and commercial catches are converted to catch in numbers at age. Separable and tuned virtual population analyses are conducted on the catch in numbers at age to obtain estimates of fishing mortality rates and population size (including recruitment to age 1). In turn, these estimates of fishing mortality rates combined with estimates of growth (length and weight), sex ratios, sexual maturity and fecundity are used to estimate yield per recruit, escapement to age 4, and static (or equilibrium) spawning potential ratio (static SPR, based on both female biomass and egg production).

Three virtual analysis approaches (separable, spreadsheet, and FADAPT) were applied to catch matrices for two time periods (early: 1986-1991, and late: 1992-1998) and two regions (Northern: North Carolina and north, and Southern: South Carolina through east coast of Florida). Additional catch matrices were developed based on different treatments for the catch-and-release recreationally-caught red drum (B2-type). These approaches included assuming 0% mortality (BASE0) versus 10% mortality for B2 fish. For the 10% mortality on B2 fish, sizes were assumed the same as caught fish (BASE1), or positive difference in size distribution between the early period and the later period (DELTA), or intermediate (PROP). Hence, a total of 8 catch matrices were developed (2 regions, and 4 B2 assumptions for 1986-1998) to which the three VPA approaches were applied. The question of when offshore emigration or reduced availability begins (during or after age 3) continues to be a source of bias that tends to result in overestimates of fishing mortality. Additionally, the continued assumption (Vaughan and Helser, 1990; Vaughan 1992; 1993; 1996) of no fishing mortality on adults (ages 6 and older), causes a bias that results in underestimates of fishing mortality for adult ages (0 versus some positive value). Because of emigration and the effect of the slot limit for the later period, a range in relative exploitations of age 3 to age 2 red drum was considered. Tuning indices were developed from the MRFSS, and state indices for use in the spreadsheet and FADAPT VPAs.

The SAFMC Red Drum Assessment Group (Appendix A) favored the FADAPT approach with catch matrix based on DELTA and a selectivity for age 3 relative to age 2 of 0.70 for the northern region and 0.87 for the southern region. In the northern region, estimates of static SPR increased from about 1.3% for the period 1987-1991 to approximately 18% (15% and 20%) for the period 1992-

1998. For the southern region, estimates of static SPR increased from about 0.5% for the period 1988-1991 to approximately 15% for the period 1992-1998.

Population models used in this assessment (specifically yield per recruit and static spawning potential ratio) are based on equilibrium assumptions: because no direct estimates are available as to the current status of the adult stock, model results imply potential longer term, equilibrium effects. Because current status of the adult stock is unknown, a specific rebuilding schedule cannot be determined. However, the duration of a rebuilding schedule should reflect, in part, a measure of the generation time of the fish species under consideration. For a long-lived, but relatively early spawning, species as red drum, mean generation time would be on the order of 15 to 20 years based on age-specific egg production. Maximum age is 50 to 60 years for the northern region, and about 40 years for the southern region. The ASMFC Red Drum Board's first phase recovery goal of increasing %SPR to at least 10% appears to have been met.

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INTRODUCTION

The status of Atlantic red drum (both northern and southern regions) was analyzed at the request of the South Atlantic Fishery Management Council. Early assessments treated the Atlantic red drum as a single stock (Vaughan and Helser, 1990; Vaughan, 1992; 1993). Those assessments were concerned only with subadult red drum (ages 1-5), and were primarily based on catch curve approaches with some application of separable virtual population analysis (SVPA). An early concern was removing the effect of emigration as a source of apparent fishing mortality. This is important for red drum because of their unique migration pattern, in which the adults are subject to greatly reduced fishing mortality. The most recent prior assessment on Atlantic red drum (Vaughan, 1996) conducted in 1995 with data through 1994, divided the Atlantic coast into two regions. The northern region consists of coastal waters of states from North Carolina and north, with landings from states north of Maryland quite rare. The southern region consists of coastal waters from South Carolina through the Atlantic (east) coast of Florida. Beginning with that assessment, additional concerns over three issues were raised: (1) increasing proportional recreational catch-and-release fish (B2-type caught fish); (2) effects of slot limits (18"-27" in the northern region and Florida, and 14"-27" for South Carolina and Georgia) introduced in 1992 on the analytic approaches used; and (3) use of calibrated virtual population analysis (VPA) approaches in addition to the separable VPA used previously. The analyses included in this report for the northern and southern regions attempt to better address those concerns. The results of these analyses were present to the South Atlantic Fishery Management Council (SAFMC) Red Drum Assessment Group in February 2000. The results of their discussions and conclusions are summarized in the Final Red Drum Assessment Group Report (Appendix A).

FISHERY-DEPENDENT DATA

Recreational Landings and Effort

Estimates of recreational catches are obtained from the Marine Fisheries Recreational Statistical

Survey (MRFSS; Gray et al., 1994) (Table 1a for northern region and Table 1b for southern Region). Those estimates are of three catch types (A, B1, and B2). Type A catches are brought to shore and are available for measurement; type B1 catches are used as bait, filleted, or discarded dead; and type B2 catches are those reported as released live. For the purposes of these analyses, a release mortality of 10% was used (Vaughan, 1992; 1993; 1996) based on Jordan (1990). Beginning about 1991 for the northern region and earlier for the southern region, an increasingly large percentage of the recreational catch is of type B2 (Figure 1a for northern region and Figure 1b for southern region). Proportional standard error (PSE) can be used as a measure of precision of catch estimates (A+B1+0.1*B2). When PSE is below 20%, precision is considered adequate by the MRFSS. For the northern region, most catch estimates since 1986 have PSE below 20%, with the exception of 1986 and 1990 (both at about 26%). For the southern region, all catch estimates since 1986 have a PSE below 20%.

Estimates of effort (trips) were obtained for 1982-1998 using programs developed by Holiman (1996) (Figure 2a for the northern region and Figure 2b for the southern region). In this report we summarize several types of trips. Target trips, for which red drum were identified as sought after, include both successful (red drum caught) and unsuccessful (red drum not caught) trips. Directed trips include target (successful or unsuccessful) trips and incidental catch (red drum caught, but not identified as sought after) trips. Catch trips include both successful target trips and incidental catch trips. From these are calculated the proportion of successful target trips from all target trips (successful and unsuccessful). Catch per trip is calculated from MRFSS data based on corresponding target catch and trips (Figure 3a for the northern region and Figure 3b for the southern region). The value in 1986 from the northern region looks particularly anomalous, and was not used in tuning.

Commercial Landings

Landings of Atlantic red drum were obtained from National Marine Fisheries Service (NMFS) Headquarters for Virginia and north, and NMFS Southeast Fisheries Science Center (SEFSC) for North Carolina and south (Table 1). Commercial landings in the northern region (Table 1a) were principally landed by gillnets (78% for the recent period 1992-1998), haul seines (13% for the same period), and pound nets (6% for the same period) (Figure 4). The remaining commercial gears (trawl and commercial lines) landed the remaining 3%. However, no data are available for estimating at-sea discards. Commercial landings in the northern region represented about 34% of total landings with recreational landings representing the remaining 66%. With the slot limit introduced in 1992, there is an increased likelihood of discards at sea because of the minimum and maximum size limits. No comparable value of precision (e.g., PSE) is available for commercial landings.

Commercial landings in the southern region (Table 1b) prior to 1988 were principally from Florida and taken with gillnets and lines (69% and 28% respectively). Recreational landings represented about 95% of the southern region landings for 1986-1987 and essentially 100% since 1988.

Length-frequency Data

Recreational length-frequency data for type A (landed whole) catches were obtained from the MRFSS. Supplemental intercept (length) data were provided by Georgia and South Carolina Departments of Natural Resources. However, no length information is available for type B1 and B2 catches. Commercial length-frequency data were updated by North Carolina Division of Marine Fisheries. Sampling intensity is based on determining landings per 100 fish length samples (C/100n) (Figure 5). As a rough reference for sampling adequacy, this value should be less than 200 t per 100 fish sampled. By this standard, adequacy of sampling from the recreational fishery was poor to marginal in 1986, 1988, and 1997 for the northern region (Figure 5a) and marginal in 1990 and 1994-1995 in the southern region (Figure 5b). Sampling in the northern region for gillnet and haul seine was generally adequate, except for 1986 for both gears and 1987 and 1988 for gillnet (Figure 5a). Sampling for the other commercial gears were not adequate, but the landings by these other gears was small relative to total landings.

The differences in pooled length-frequency distributions from the MRFSS before (1986-1991) and after (1992-1998) changed management regulations were used to approximate the size distribution of regulatory discards (B2 for recreational fishing component). These comparisons were done separately for each region (Figure 6a for the northern region and Figure 6b for the southern region). Length intervals displaying large positive differences (more abundant in the early period compared to the latter period) suggested that most of the B2 fish (live discards) were sublegals (<18" for the northern region, see Figure 6a; and <14" for the southern region, see Figure 6b). Length frequencies were developed based on these positive differences (Figs. 7a and 7b) by setting negative differences to zero and normalizing total proportion to one. An analysis of North Carolina commercial length-frequency data gave similar results (e.g., gillnet, Figure 8).

FISHERY-INDEPENDENT DATA

The North Carolina Division of Marine Fisheries (NCDMF) provided estimates of juvenile (age-0) red drum catch per seine sample for four coastal regions of North Carolina and overall from 1991-1998 (Figure 9a). The four coastal regions include the northern outer banks, southern outer banks, Pamlico/Neuse Rivers, and White Oak/New Rivers/Alligator Bay. Number of samples ranged from 16-29 per year in the northern outer banks, 18-24 in the southern outer banks, 34-51 in the Pamlico/Neuse Rivers, and 9-30 in White Oak/New Rivers/Alligator Bay. There appear to be both years of relatively high recruitment and years of relatively low recruitment with no obvious temporal trend (Figure 9a).

South Carolina Department of Natural Resources (SCDNR) provided age-specific stratified mean catch per set from trammel net (Figure 9b). These data, including standard errors, are based on monthly random net sets between mid-ebb and low tides. Five strata are included, although only two (lower Charleston Harbor and lower Wando River) have been sampled for the entire time period (1991-1998). A downward trend is noted in both the trammel net catch per unit effort (CPUE) and Pr{success} (Figure 9b).

Florida Department of Environmental Protection (FLDEP) provided indices from the juvenile monitoring program for the northern Indian River (inside Cape Canaveral and south) (Figure 9c). These indices are based on least-squares means and standard errors from a general linear model that incorporates environmental, temporal, and geographical variables to isolate the year effect. The Florida indices are based on fishery independent monitoring (FIM) of young-of-year (<300 mm SL) and older (300-600 mm SL) catch rates. Young-of-year (YOY) index was matched in the VPAs with early age-1 based on our calendar year (about 4 months in age), and older fish were matched with early age 2 and possibly age 3. While recruitment levels (YOY) show no obvious trends, there appears to be a decline in older fish (~age 2) (Figure 9c).

CATCH-AT-AGE MATRICES

Age and Growth

Age-length data for the northern region were provided by North Carolina Division of Marine Fisheries (4,214 fish from 1987-1998) and Old Dominion University (via Virginia Marine Resources Commission; 36 fish from 1998). Age-length data for the southern region were provided by South Carolina Department of Natural Resources (35,626 fish from 1985-1998), Georgia Department of Natural Resources (2,837 fish from 1988-1998), and Florida Department of Environmental Protection (866 fish from 1981-1997). These data were used to estimate von Bertalanffy-type growth equations (Figure 10a for the northern region and Figure 10b for the southern region) and to develop age-length keys for converting size at age to numbers at age. To convert catch at size based on calendar year to numbers at age also based on calendar year, it is necessary that the age assigned in the development of the age-length key be based on the calendar year. With 1 September used as the theoretical birthdate by the Atlantic coast states, an age 1 fish (January through December of the following calendar year) would range in actual age from 4 months to 16 months. As in Vaughan (1996), growth data were fit to both the standard and linear versions of the von Bertalanffy (1938) growth equations using PROC NLIN in SAS (SAS Institute, 1987). The extra parameter of the linear version (L_∞ in the standard version replaced by $b_0 + b_1*t$) is significantly different from zero. Thus, the linear version is used in preference to the standard von Bertalanffy growth equation in subsequent population models. Parameter values for the standard and linear versions by region are summarized below:

Von Bertalanffy Parameters for Atlantic red drum by region:

	North Region	South Region
Sample Size (n)	4,244	36,344
Standard		
L_∞	47.4 (0.06)	41.8 (0.02)
K	0.15 (0.002)	0.24 (0.001)
t_0	-2.15 (0.088)	-0.72 (0.017)
Linear		
b0	41.3 (0.13)	39.8 (0.05)
b1	0.15 (0.023)	0.07 (0.006)
K	0.29 (0.005)	0.28 (0.002)
t0	-0.31 (0.052)	-0.40 (0.017)

Female maturity schedule, as estimated by Ross et al. (1995) (Figure 11), was used for both regions.

Catch Matrices

Four catch matrices were developed based on differing assumptions concerning the size characteristics of type B2 catches when estimating the catch in numbers by size category prior to applying the age-length keys. The catch matrix referred to as BASE0 assumes complete survival of all type B2 catches. The remaining catch matrices assume 10% mortality for the type B2 catches. The catch matrix referred to as BASE1 uses the same MRFSS length frequency for type B2 catches as that for type A catches. The catch matrix referred to as DELTA uses the positive differences in MRFSS length frequency between the early period (1986-1991) and later period (1992-1998) (Figure 7a-b). The catch matrix referred to as PROP uses a weighted average or proportion of the MRFSS length frequencies from BASE1 and DELTA catch matrices. The DELTA catch matrix will suggest that there were more smaller, and hence younger, fish in the landings than the BASE1 catch matrix, with PROP being intermediate between the two. The DELTA catch matrix (and to a lesser extent the PROP catch matrix) imply more, younger fish are caught relative to older fish than BASE0 or BASE1 catch matrices.

ESTIMATES OF MORTALITY RATES AND STOCK SIZE

Natural Mortality

Natural mortality M was estimated from the relationship based on size at age in Boudreau and Dickie (1989) (Figure 12a for the northern region and Figure 12b for the southern region). Separate estimates were made of M for subadults (mean of 0.20 for the northern region and 0.23 for the southern region from ages 1-5) and adults (mean of 0.12 for the northern region and 0.13 for the southern region from ages 6 and older).

Separable Virtual Population Analysis (SVPA)

As in earlier assessments of red drum, SVPA was used to estimate population numbers and fishing mortality at age for the subadults. The separability assumption presumes that fishing mortality at age can be decomposed into year and age components (Doubleday, 1976; Pope and Shepherd, 1982). Thus a fixed selectivity pattern is estimated over the time period to which this approach is applied. For these analyses, we divided the catch at age data (ages 1-5 and years 1986-1998) into two time periods (early: 1986-1991 and late: 1992-1998) during which the management regimes were constant. We dropped 1986-1987 from the early period for the southern region, because of the drastic change in selectivity with the severely reduced commercial fishery in Florida after 1987.

The SVPA computer program (Clay, 1990) requires one to specify both a fully-recruited reference age and the relative selectivity of a second age. Ordinarily, the selectivity of the first fully recruited age and the oldest age in the analysis are assumed equal. This is not appropriate for red drum analyses, because of reduced availability at age 5. For the early time period, the selectivity on age 3 was assumed equal to the selectivity on age 2 (F_3=F_2). For the later period two different assumptions were compared. First, the selectivity on age 3 was assumed equal to that of age 2, as with the early time period. This was probably not a good assumption because a slot limit was imposed by management during 1992-1998; i.e., fish were not allowed to be retained if less than 18" TL or greater than 27" TL for the northern region, and slot of 14" to 27" for the southern region. Florida instituted a slot of 18"-27" with a 1 fish bag limit in late 1987. Additionally, the slot limit issue was complicated in the northern region because one fish of a recreational five-fish bag limit could exceed the 27" TL during the study period. The slot limit issue was also complicated in the southern region with Florida (18"-27" TL) having a different slot limit than South Carolina and Georgia (14"-27" TL). The regulatory discard of red drum by the commercial fishery (especially in the northern region) were not included in this assessment due to lack of data.

Investigation of size distributions at ages 2 and 3 relative to the slot limit suggested that age 3 fish were about 43% legally available relative to age 2 for the northern region (Figure 13a) and about 87% legally available for the southern region (based on Georgia and South Carolina slot limit, Figure 13b). Hence, a second series of SVPA runs was made where the selectivity of age 3 was assumed to be 0.43 times the selectivity of age 2 (F_3=0.43*F_2) for the northern region and the selectivity of age 3 was assumed to be 0.87 times the selectivity of age 2 (F_3=0.87*F_2) for the southern region. These two extremes probably encapsulate a "best estimate" of F from the SVPA approach. Average estimates of fishing mortality rates at age from the SVPA are summarized for each period and catch matrix (Table 2a for the northern region and Table 2b for the southern region). This approach does not use any auxiliary information (e.g., MRFSS CPUE or fishery-independent information), and relies completely on the specification of the catch-at-age matrices and assumptions used to develop them.

Spreadsheet Virtual Population Analysis

From a spreadsheet-based catch-age analysis (Carmichael et al., 1999), a separable, forward projection population model was solved iteratively using the Excel Solver function. This approach permits the use of auxiliary information.

Analysis of the northern region used catch matrices for 1986-1998 at ages 1-5, with auxiliary information that included the NCDMF juvenile abundance index (JAI) and MRFSS target CPUE as tuning indices. The JAI was used to tune recruitment estimates for 1992-1998, with 1997 omitted as an outlier (it is suspected that hurricanes contributed to the low 1997 JAI value), while the CPUE is used to tune the total annual abundance from 1987 to 1998. The model estimated 40 parameters from 96 data points by minimizing an objective function that incorporates lognormal errors in predicted catch at age, JAI, and CPUE values. Two selectivity periods (1986-1991 and 1992-1998) were used to account for regulatory changes in the fishery, and selectivity for ages 2 and 3 are fixed at the same values used in the SVPA assessment runs ($F_3 = F_2$ for early and F_3=0.43*F_2 for later). Results are summarized in terms of average fishing mortality at age for each period and catch matrix (Table 3a).

Analysis of the southern region used catch matrices for 1988-1998 at ages 1-5, with auxiliary information that included the MRFSS targeted CPUE and South Carolina trammel net survey catch at ages 1-5 as tuning indices. The CPUE was used to tune total abundance estimates for 1986-1998, while the South Carolina survey was used to tune annual abundance at age from 1992 to 1998. The model estimated 36 parameters on the log scale from 101 data points by minimizing an objective function that incorporates lognormal errors in predicted catch at age, South Carolina abundance survey, and CPUE values. Two selectivity periods (1988-1991 and 1987-1992) were used to account for regulatory changes in the fishery, and selectivity for ages 2 and 3 are fixed at 1.00. Age-1 selectivity was fixed at 0.2 for the early period and 0.15 for the late period. These values were the best estimates as based on initial model runs and further supported by sensitivity analysis. Average estimates of fishing mortality rates at age from the spreadsheet VPA are summarized for each period and catch matrix (Table 3b).

FADAPT Virtual Population Analysis

Restrepo's (1996) FADAPT program, modified from Gavaris (1988), does not assume separability and allows for calibration (or tuning) by a series of indices of abundance at age. An estimate of selectivity for the most recent year (1998) is specified based on the SVPA runs for the late time period.

For the northern region, the NC DMF JAI, and MRFSS-based age-specific CPUE and Pr{success} values are used for tuning. Additional FADAPT runs were made on the early period. Results are summarized in terms of average fishing mortality at age for each period and catch matrix (Table 4a).

For the southern region, the MRFSS-based age-specific CPUE and Pr{success} values, South Carolina trammel net CPUE and Pr{success}, and Florida Fishery Independent Monitoring (FIM) of young-of-year and older fish CPUE indices are used for tuning. Average estimates of fishing mortality rates at age for the FADAPT VPA are summarized for each period and catch matrix (Table 4b).

ESCAPEMENT AND STATIC SPAWNER POTENTIAL RATIO (SPR)

Estimates of escapement to age 4 and static SPR (%MSP in Gabriel et al., 1989) are summarized by VPA approach, catch-at-age matrix (assumption on B2), temporal period (early vs. late), and where appropriate assumption on selectivity of age 3 relative to age 2. Because of concerns about retrospective error, values for 1998 were not included in the period averaging. Escapement and static SPR estimates are summarized separately by region in Tables 2-4. Escapement and static SPR were found to be generally low during the early period (1986-1991 for northern region and 1988-1991 for southern region), and higher in the later period (1992-1997) for all catch matrices, VPA approaches, and regions. Hence, the management actions taken for Atlantic red drum effective with the 1992 fishing year were successful to the extent that they were associated with a discernable improvement in escapement and static SPR values found for the Atlantic red drum stock compared with very low levels during the early period.

In general, estimates of escapement and static SPR are lower for VPAs based on the DELTA and PROP catch matrices compared to the BASE0 and BASE1 catch matrices. Recall that the BASE0 catch matrix assumes no release mortality for the recreational fishery, and the BASE1 catch matrix assumes that the size of the released red drum from the recreational fishery are the same as the retained. Both of these assumptions are likely wrong. The DELTA catch matrix attempts to estimate the size of the released recreational red drum for the late period from the difference in size frequency noted between the two time periods. The PROP is intermediary between the DELTA catch matrix and BASE1 catch matrix for the late period. Hence, the DELTA or PROP catch matrices probably provides the more realistic treatment for use as catch matrices in a VPA.

For the SVPA on the northern region catch matrices, when the reduced selectivity on age 3 was set to 0.43 times the selectivity of age 2, considerably larger values of escapement and static SPR were found compared to the assumption of equal selectivity between ages 2 and 3. Because the management regime was not a true slot limit (allowing 1 fish over the slot recreationally) and no data was available for commercial regulatory discards, these estimates of escapement and static SPR based on the reduced selectivity of age 3 relative to age 2 are likely biased high. Hence, true escapement and static SPR values are likely well above those based on identical selectivity, but not quite as high as those using 43% selectivity of age 3 relative to age 2. Because the difference in selectivity assumption is narrower when using SVPA for the southern region catch matrices (87% versus 100%), the estimates of escapement and static SPR are also more similar.

For the northern region, the Spreadsheet VPA approach suggested generally higher escapement and static SPR values than the FADAPT VPA approach, especially for those based on the DELTA and PROP catch matrices. For the southern region, there was much less discrepancy between these VPA approaches for the DELTA and PROP catch matrices, although the discrepancy remained for the BASE0 and BASE1 catch matrices. Note that the FADAPT calibration method is less constrained than the Spreadsheet VPA method, especially with respect to any separability assumption.

The sensitivity of FADAPT to assumption of selectivity was investigated. In general, the greater the selectivity of age 3 relative to age 2, the smaller the resultant estimates of escapement and static SPR. In particular, northern region estimates of escapement and static SPR based on the DELTA matrix declined with increasing selectivity of age 3 relative to age 2 (Figure 14a). Similarly, southern region estimates of escapement and static SPR based on the DELTA matrix declined with increasing selectivity of age 3 relative to age 2 (Figure 14b). The ratio of catch at age 3 to age 2 was compared between MARFIN (trammel net) and MRFSS for data from Georgia (0.95 for MARFIN compared to 2.05 from MRFSS from Table 3, Woodward et al., 1999) and from South Carolina (1.04 from MARFIN compared to 2.08 from MRFSS from Table 14, Wenner, 1999). Surprisingly, MARFIN data from North Carolina (Paramore, 1999) suggested a greater slope (higher Z) than the MRFSS data (2.30 from MARFIN compared to 1.29 for MRFSS). This difference may be, in part, due to the general availability of the older, larger red drum to the recreational fishery in North Carolina in its large bays and sounds as compared to states to the south. The usefulness of these data to determine the relative selectivity of age 3 to age 2 is unclear. It does some clear that both regions have likely met their initial goal of reducing F such that static SPR is above 10%. However, it seems unlikely that either region has lowered F sufficiently to meet the SAFMC's goal of 30% static SPR.

A summary of the conclusions of the SAFMC Red Drum Assessment Group based on this stock assessment was provided to the SAFMC and is included in this document as Appendix A. "Best estimates of static SPR and escapement were obtained from specific selectivity assumptions based on the Red Drum Assessment Group recommendations. The selectivity of age 3 relative to age 2 assumed for the northern region was 0.7 and for the southern region was 0.87. The Atlantic coast red drum stock is overfished with best estimates of SPR to be 18% (15% and 20%) for the northern region and 15% for the southern region. In addition escapement is estimated at 18% for the northern region and 17% for the southern region. The estimate in the northern region was considered by the Assessment Group to be an overestimate because the additional unaccounted discard mortality from net fisheries. "

RESEARCH NEEDS

Primary needs for future stock assessments include continued and improved collection of the following data sets: (1) Catch statistics (sampling of at-sea discards is a major data gap); (2) length-frequency distributions by gear (major need described below); and (3) age-length keys. It is important to continue to increase the number of MRFSS intercepts, because recreational landings represent over 90% of total landings by number coastwide, over 99% in the southern region, and 66% in the northern region.

There is a need for information on at-sea discards from the commercial fishery, primarily in the northern region for both amount of discard and size information. In addition, there is a need for size information on recreational discards (B2 fish) for both regions. Information is needed to better understand the relative selectivity of ages because this has been a major stumbling block in assessing this stock. This is related in part to the use of slot limits in management and migration patterns of the stocks.

Population models still require better estimates of natural mortality rates (subadult M_1 and adult M_2), to which VPA results can be quite sensitive.

Estimates of fecundity as a function of length or weight would prove useful, although it does not appear to be unreasonable to assume similarity to red drum from the Gulf of Mexico (Hoese et al., 1991). As used in this and earlier stock assessments, it is not necessary that the absolute value of the estimates be correct, but that the rate of increase in egg production with female age be similar.

Continued standardized sampling of subadults (ages 1-5) is needed to develop long-term indices of recruitment. This is necessary to permit short-term warning of potential recruitment failure.

The evidence of such failures typically appears in the catch or other fishery statistics too late for management action to be effective. Furthermore, fishery-independent indices are highly desirable as indices of abundance for use in tuning approaches to VPA (Pope and Shepherd, 1985; National Research Council, 1998). These calibrated VPAs require one or more indices of abundance, and permit greater confidence in the more recent estimates of fishing mortality rates (and population size). In particular, these methods may increase our confidence in the detection of a decline in fishing mortality rates in the most recent years since management actions have taken place.

Monitoring of adult red drum is needed to provide a fishery-independent index of spawning stock (e.g., possibly by aerial counting of schools as in the Gulf of Mexico). Conceptually, the application of a VPA to the entire age structure (i.e., through age 50 or 55) is not practical. There are too many ages with relatively small growth from ages 6 through 55, thus an age-length key is not likely to be useful in assigning age to fish sizes. Furthermore, too few red drum of these ages are caught for application of VPA techniques.

Stock status is often assessed from two perspectives. What is the current level of the spawning stock biomass, and are fish being removed at too great a rate? There are currently no data available from which to estimate present levels of adult or spawning stock biomass. Hence, this report addresses the second perspective, but not the first. The population models used in this assessment (specifically escapement and percent maximum spawning potential) are based on equilibrium assumptions, so that the model results in this report are only valid in assessing long-term effects based on current removal (fishing) rates.

However, two data sets allow a very crude look at adult abundance. Age frequency distributions derived from North Carolina aging data were compared for several time periods (Figure 15). Data for 1969-1971 were provided by William Foster (unpublished data, available from NCDMF, Morehead City, NC), while data for two later time periods (1986-1991 and 1992-1998) were provided by North Carolina Division of Marine Fisheries (NCDMF). These data suggest a greater proportion of older fish were available during 1969-1971 than more recently. Citation data, number of fish exceeding a specified size, have been made available by NCDMF and Virginia Marine

Resources Commission (VMRC) (Figure 16). The citation data also suggest that older red drum were more available both in the late 1960s (VMRC data only) and late 1990s, with lower availability in the interim. However, there have been many qualitative changes to the collection of this information which can obscure or confound any conclusions that might be drawn from them over longer time periods.

Any rebuilding schedule must take into account the generation time of red drum. Maximum age of red drum from the North Carolina aging data was 62 years with several in their early to mid 50s. And yet the onset of sexual maturity is significant with age 3 females (Figure 11). Because Atlantic red drum are both long-lived and mature relatively young, the generation time is on the order of 15-20 years, calculated from the mean age at reproduction of a cohort of females in the unfished stock (i.e., mean age of mature females weighted by age-specific egg production when F=0) (Charlesworth, 1980).

There is no current estimate of present levels of the adult red drum stocks. Because the development of a rebuilding schedule assumes that information is available as to the current level of the adult stock, no rebuilding schedule can presently be developed for red drum.

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Table 1a. Red drum catches from recreational and commercial fisheries, 1981-1994 (northern region). Recreational catches are in numbers and weight, commercial catches are in weight, and total catches are in weight. Mean weight of B2 is assumed the same as the expanded mean weight of A. This assumption is used here only for comparison with commercial landings in weight.

Year	Recreational[a] Numbers A+B1 (1000)	Recreational[a] Numbers B2 (1000)	Recreational[a] Weight A+B1+0.1*B2 (1000 lbs)	Commercial Weight (1000 lbs)	Total Weight (1000 lbs)
1981	65.3	3.6	384.6	93.6	478.2
1982	16.4	0.0	34.1	54.4	88.5
1983	116.9	1.9	163.8	261.7	425.5
1984	110.2	2.9	1161.8	285.7	1447.5
1985	22.1	1.1	70.7	153.9	224.6
1986	58.4	7.6	931.3	255.4	1186.7
1987	63.3	18.5	197.1	252.3	449.4
1988	146.9	28.8	467.3	232.5	699.8
1989	75.4	17.5	246.5	283.7	530.2
1990	34.4	13.4	309.8	184.8	494.6
1991	58.5	140.1	175.1	128.3	303.4
1992	36.9	75.9	192.1	131.7	323.8
1993	63.5	232.7	402.5	246.8	649.3
1994	30.3	118.3	254.3	152.5	406.8
1995	87.3	187.7	514.4	251.8	766.2
1996	35.6	36.7	215.1	116.1	331.2
1997	10.5	366.5	153.4	56.7	210.1
1998	127.7	296.1	715.0	301.8	1016.8

[a] Definitions of catch type (Essig et al., 1991):

A = "fish brought ashore in whole form which were available for identification, enumeration, weighting and measuring by the interviewers",

B = "those not brought ashore in whole form were separated into":

B1 = "those used as bait, filleted, or discarded dead",

and

B2 = "those released alive".

Table 1b. Red drum catches from recreational and commercial fisheries, 1981-1994 (southern region). Recreational catches are in numbers and weight, commercial catches are in weight, and total catches are in weight. Mean weight of B2 is assumed the same as the expanded mean weight of A. This assumption is used here only for comparison with commercial landings in weight.

Year	Recreational[a] Numbers A+B1 (1000)	Recreational[a] Numbers B2 (1000)	Recreational[a] Weight A+B1+0.1*B2 (1000 lbs)	Commercial Weight (1000 lbs)	Total Weight (1000 lbs)
1981	108.9	9.5	377.7	259.5	637.2
1982	395.6	16.1	865.3	141.6	1006.9
1983	506.2	62.9	977.3	109.2	1085.5
1984	937.1	51.4	1462.0	136.7	1598.7
1985	979.1	216.4	2170.1	95.8	2265.7
1986	408.9	180.2	1075.1	92.6	1167.7
1987	711.7	695.2	1598.3	62.1	1660.4
1988	444.5	680.5	1649.1	3.3	1652.4
1989	213.8	286.3	757.0	4.1	761.1
1990	239.3	327.5	1196.8	2.8	1199.6
1991	391.4	838.5	1463.4	3.2	1466.6
1992	300.7	459.2	1135.2	1.8	1137.0
1993	290.0	752.4	1195.1	2.5	1197.6
1994	384.7	1162.0	1638.2	2.1	1640.3
1995	451.7	1414.9	1857.7	2.5	1860.2
1996	327.6	708.7	1370.9	2.3	1373.2
1997	240.0	743.9	1001.2	4.1	1005.3
1998	179.4	599.2	942.0	3.1	945.1

[a] Definitions of catch type (Essig et al., 1991):

A = "fish brought ashore in whole form which were available for identification, enumeration, weighting and measuring by the interviewers",

B = "those not brought ashore in whole form were separated into":

B1 = "those used as bait, filleted, or discarded dead",

and

B2 = "those released alive".

Table 2a. Red drum mean fishing mortality rates by period for northern region from different catch-at-age matrices from the separable VPA (SVPA) program (M_1 = 0.20 for ages 0-5). In addition, estimated values for escapement to age 4 and static spawning potential ratio (static SPR) based on female biomass are presented. Adult M (ages 6+) is 0.12.

Values	BASE0	BASE1	DELTA	PROP
		Early (1986-1991) **[F_3 = 1.0*F_2]**		
1	1.25	1.23	1.23	1.23
2	1.60	1.58	1.58	1.58
3	1.60	1.58	1.58	1.58
4	0.29	0.29	0.29	0.29
5	0.11	0.12	0.12	0.12
Escapement (%)	0.9	0.9	0.9	0.9
Static SPR (%)	1.0	1.0	1.0	1.0
		Late (1992-1997) **[F_3 = 1.0*F_2]**		
1	0.11	0.13	0.19	0.17
2	1.16	1.09	1.26	1.19
3	1.16	1.09	1.26	1.19
4	0.17	0.13	0.22	0.19
5	0.03	0.03	0.05	0.04
Escapement (%)	7.6	8.8	5.3	6.4
Static SPR (%)	8.1	9.3	5.7	6.9
		Late (1992-1997) **[F_3 = 0.43*F_2]**		
1	0.09	0.10	0.16	0.14
2	0.66	0.60	0.76	0.69
3	0.29	0.26	0.33	0.30
4	0.02	0.01	0.03	0.02
5	0.003	0.002	0.004	0.003
Escapement				

(%)	35.1	37.8	27.8	31.7
Static SPR (%)	35.4	38.1	28.1	32.0

Table 2b. Red drum mean fishing mortality rates by period for southern region from different catch-at-age matrices from the separable VPA (SVPA) program (M_1 = 0.23 for ages 0-5). In addition, estimated values for escapement to age 4 and static spawning potential ratio (static SPR) based on female biomass are presented. Adult M (ages 6+) is 0.13.

Values	BASE0	BASE1	DELTA	PROP
		Early (1988-1991) **[F_3 = 1.0*F_2]**		
1	0.31	0.31	0.31	0.31
2	1.89	1.87	1.87	1.87
3	1.88	1.87	1.87	1.87
4	1.85	1.87	1.87	1.87
5	0.19	0.19	0.19	0.19
Escapement (%)	0.3	0.3	0.3	0.3
Static SPR (%)	0.8	0.8	0.8	0.8
		Late (1992-1997) **[F_3 = 1.0*F_2]**		
1	0.07	0.07	0.14	0.09
2	0.28	0.27	0.47	0.33
3	0.28	0.27	0.47	0.33
4	0.12	0.11	0.28	0.16
5	0.03	0.03	0.09	0.04
Escapement (%)	47.4	48.5	25.9	40.0
Static SPR (%)	47.6	48.7	25.7	40.1
		Late (1992-1997) **[F_3 = 0.87*F_2]**		
1	0.07	0.07	0.13	0.09
2	0.23	0.23	0.41	0.28
3	0.21	0.20	0.35	0.25
4	0.07	0.07	0.18	0.09
5	0.02	0.02	0.05	0.02
Escapement				

(%)	55.9	56.7	34.3	48.8
Static SPR (%)	56.1	57.0	34.3	48.9

Table 3a. Red drum mean fishing mortality rates by period for northern region from different catch-at-age matrices from the spreadsheet VPA program (M_1 = 0.20 for ages 0-5). In addition, estimated values for escapement to age 4 and static spawning potential ratio (static SPR) based on female biomass are presented. Adult M (ages 6+) is 0.12.

Values	BASE0	BASE1	DELTA	PROP
Early (1986-1991) **[F_3 = 1.0*F_2]**				
1	0.92	0.92	0.93	0.93
2	1.10	1.17	1.12	1.14
3	1.10	1.17	1.12	1.14
4	0.15	0.17	0.16	0.16
5	0.06	0.07	0.06	0.06
Escapement (%)	3.8	3.2	3.6	3.4
Static SPR (%)	3.9	3.4	3.7	3.6
Late (1992-1997) **[F_3 = 0.43*F_2]**				
1	0.07	0.08	0.13	0.12
2	0.51	0.69	0.62	0.64
3	0.22	0.30	0.27	0.27
4	0.02	0.03	0.03	0.03
5	0.005	0.008	0.007	0.008
Escapement (%)	44.2	33.4	35.0	35.1
Static SPR (%)	44.4	33.7	35.1	34.7

Table 3b. Red drum mean fishing mortality rates by period for southern region from different catch-at-age matrices from the spreadsheet VPA program (M_1 = 0.23 for ages 0-5). In addition, estimated values for escapement to age 4 and static spawning potential ratio (static SPR) based on female biomass are presented. Adult M (ages 6+) is 0.13.

Values	BASE0	BASE1	DELTA	PROP
		Early (1988-1991) **[F_3 = 1.0*F_2]**		
1	0.23	0.24	0.28	0.27
2	1.16	1.19	1.39	1.37
3	1.16	1.19	1.39	1.37
4	1.16	1.19	1.39	1.37
5	0.12	0.12	0.13	0.12
Escapement (%)	2.2	2.4	1.2	1.3
Static SPR (%)	3.2	3.5	2.0	2.1
		Late (1992-1997) **[F_3 = 1.0*F_2]**		
1	0.05	0.05	0.10	0.08
2	0.36	0.37	0.67	0.56
3	0.36	0.37	0.67	0.56
4	0.27	0.28	0.57	0.53
5	0.10	0.10	0.28	0.24
Escapement (%)	34.3	35.4	13.5	17.7
Static SPR (%)	33.6	34.7	12.8	16.8

Table 4a. Red drum mean fishing mortality rates by period for northern region from different catch-at-age matrices from the FADAPT program (M_1 = 0.20 for ages 0-5). In addition, estimated values for escapement to age 4 and static spawning potential ratio (static SPR) based on female biomass are presented. Adult M (ages 6+) is 0.12.

Values	BASE0	BASE1	DELTA	PROP
Early (1986-1991) [$F_3 = 1.0*F_2$]				
1	1.02	1.03	1.03	1.03
2	1.35	1.36	1.36	1.36
3	1.63	1.67	1.67	1.67
4	0.36	0.39	0.39	0.39
5	0.18	0.20	0.20	0.20
Escapement (%)	1.3	1.2	1.2	1.2
Static SPR (%)	1.4	1.3	1.3	1.3
Late (1992-1997) [1998: $F_3 = 0.43*F_2$]				
1	0.15	0.13	0.23	0.20
2	0.59	0.61	0.71	0.71
3	0.39	0.49	0.30	0.35
4	0.03	0.04	0.03	0.03
5	0.006	0.009	0.004	0.005
Escapement (%)	31.3	27.7	28.2	27.7
Static SPR (%)	31.7	28.2	28.5	28.0

Table 4b. Red drum mean fishing mortality rates by period for southern region from different catch-at-age matrices from the FADAPT program (M_1 = 0.23 for ages 0-5). In addition, estimated values for escapement to age 4 and static spawning potential ratio (static SPR) based on female biomass are presented. Adult M (ages 6+) is 0.13.

Values	BASE0	BASE1	DELTA	PROP
		Early (1988-1991) **[F_3 = 1.0*F_2]**		
1	0.39	0.37	0.37	0.37
2	1.26	1.22	1.19	1.22
3	0.93	0.91	0.82	0.86
4	1.51	1.50	1.12	1.28
5	0.55	0.52	0.28	0.37
Escapement (%)	0.1	0.1	0.1	0.1
Static SPR (%)	0.5	0.5	0.5	0.5
		Late (1992-1997) **[1998: F_3 = 0.87*F_2]**		
1	0.09	0.10	0.16	0.13
2	0.32	0.34	0.49	0.42
3	0.61	0.63	0.62	0.65
4	0.66	0.69	0.63	0.70
5	0.63	0.67	0.39	0.56
Escapement (%)	18.6	17.3	16.9	17.3
Static SPR (%)	14.5	13.4	15.1	14.4

Figures 1a. Red drum recreational landings (northern region) by catch type and proportional standard error (PSE), 1979-1998.

Figure 1b. Red drum recreational landings (southern region) by catch type and proportional standard error (PSE), 1979-1998.

Figure 2a. Red drum recreational effort (targeted trips) and probability of success for northern region, 1982-1998.

Figure 2b. Red drum recreational effort (targeted trips) and probability of success for southern region, 1982-1998.

Figure 3a. Red drum recreational catch per unit effort based on targeted catch and trips for northern region, 1981-1998.

Figure 3b. Red drum recreational catch per unit effort based on targeted catch and trips for southern region, 1981-1998.

Figure 4. Red drum commercial landings by gear for northern region, 1972-1998.

Figure 5a. Red drum sampling intensity (catch/100n) for northern region, 1986-1998.

Figure 5b. Red drum augmented sampling intensity (catch/100n) for southern region, 1986-1998.

Figure 6a. Northern region: Red drum recreational length frequencies for two time periods (Early: 1986-1991 and Late: 1992-1998) and difference between periods below.

Figure 6b. Southern region: Red drum recreational length frequencies for two time periods (Early: 1986-1991 and Late: 1992-1998) and difference between periods below.

Figure 7a. Red drum recreational B2 (reported released alive) length frequency for DELTA catch-at-age matrix applied to 1992-1998 for northern region.

Figure 7b. Red drum recreational B2 (reported released alive) length frequency for DELTA catch-at-age matrix applied to 1992-1998 for southern region.

Figure 8. Northern region: Red drum commercial length frequencies for two time periods (Early: 1986-1991 and Late: 1992-1998) and difference between periods below.

Figure 9a. North Carolina red drum juvenile (age-0) abundance survey, 1991-1998.

Figure 9b. South Carolina red drum trammel net survey, 1992-1998.

Figure 9c. Florida red drum YOY and older FIM survey, 1990-1997.

Figure 10a. Comparison of von Bertalanffy growth models of red drum from the northern region.

Figure 10b. Comparison of von Bertalanffy growth models of red drum from the southern region.

Figure 11. Red drum female maturity schedule, observed and logit model fit.

Figure 12a. Red drum natural mortality rate, M, for subadults (0.2) and adults (0.12) for the northern region.

Figure 12b. Red drum natural mortality rate, M, for subadults (0.23) and adults (0.13) for the southern region.

Figure 13a. Effect of slot limit on relative selectivity of size at age based on normalized North Carolina aging data. Selectivity of age 3 is 43% of age 2.

Figure 13b. Effect of slot limit on relative selectivity of size at age based on normalized southern region aging data. Selectivity of age 3 is 87% of age 2.

Figure 14a. Sensitivity of FADAPT to varying assumptions of selectivity of age 3 relative to age 2 for northern region.

Figure 14b. Sensitivity of FADAPT to varying assumptions of selectivity of age 3 relative to age 2 for southern region.

Figure 15. Red drum year classes for different time periods from North Carolina aged data as percent of total fish collected.

Figure 16. Citation data for red drum from North Carolina and Virginia.

Appendix A.

Final
2000 REPORT OF THE
RED DRUM ASSESSMENT GROUP

Prepared by the SAFMC Red Drum Assessment Group

APRIL 2000

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A publication of the South Atlantic Fishery Management Council pursuant to National Oceanic and Atmospheric Administration

1. Background

The Atlantic States Marine Fisheries Commission (ASMFC) adopted a *Fishery Management Plan (FMP) for Red Drum* in 1984 (ASMFC, 1984). The original management unit included the states from Florida to Maryland. In 1988, the Interstate Fisheries Management Program (ISFMP) Policy Board requested that all states from Florida to Maine implement plan requirements to prevent development of northern markets for southern fish. This action was the first of two revisions to the 1984 plan. The second was the adoption of the South Atlantic Council's Red Drum Fishery Management Plan (SAFMC, 1990) as Amendment 1 to the Interstate plan (ASMFC, 1991).

The South Atlantic Council's Red Drum Fishery Management Plan was approved October 12, 1990. In addition, Amendment 1 to the Federal plan (SAFMC, 1998b), specifies Maximum Sustainable Yield (MSY) at 30% Spawning Potential Ratio (SPR), Optimum Yield at 40% SPR and an overfishing level <30% SPR. Amendment 2 (SAFMC, 1998), as part of a comprehensive habitat amendment, identified, described and recommended measures to protect Essential Fish Habitat (EFH) and EFH Habitat Areas of Particular Concern for Red Drum.

The original Federal plan specifies that National Marine Fisheries Service (NMFS) provide an annual update on the status of Atlantic coast red drum. The report is to include an update of the stock assessment for Atlantic coast red drum; an update of the estimate of maximum sustainable yield; the best estimate of the standing stock and its age composition; spawning stock requirements and escapement levels needed to meet these requirements; a summary of current and historical information on the migratory movements of the stock; and available social and economic data for the fishery.

The assessment is to be reviewed by a Council-appointed stock assessment review group. In order to assure continued cooperation and coordination with the Atlantic States Marine Fisheries Commission, the Council appointed members of the Commission's red drum technical monitoring committee. This report is based on the review of the techniques and results of the 2000 stock assessment that took place at the Council office on February 22, 2000.

II. Data Used in the 1999/2000 Assessment

A. Recreational Catch and Length Frequency Data

Recreational landings and length frequency data were obtained from NMFS Marine Recreational Fisheries Statistics Survey. Estimated recreational catch of red drum in the northern region of the Atlantic ranged from 1,161,800 in 1984 to 34,000 in 1982. In the southern region, recreational landings ranged from 2,170,100 pounds in 1985 to 377,700 pounds in 1981. In 1995 landings reached a second peak of 1,857,700 pounds and declined continuously to 942,000 in 1998.

Estimates of recreational catches are obtained from the Marine Fisheries Recreational Statistical Survey (Gray et al. 1994). Those estimates are of three catch types (A, B1, and B2). Type A catches are brought to shore and available for measurement, type B1 catches are used as bait, filleted, or discarded dead; and type B2 catches are those reported as released live. For the purposes of these analyses, a release mortality of 10% has been used (Vaughan, 1992; 1993; 1996) based on Jordan (1990). Beginning about 1991 for the northern region and earlier for the southern region, an increasingly large percentage of the recreational catch is of type B2. Proportional standard error (PSE) is a measure of precision of catch estimates. When this value is below 20% precision is considered adequate. For the northern region beginning with 1986, catch estimates for 1986 and 1990 have PSE above 20% (both at about 26%). For the southern region, all catch estimates since 1986 have a PSE below 20%.

Estimates of effort (trips) were obtained for 1982-1998 using programs developed by Holiman (1996). In this report we summarize several types of trips : 1) Directed trips include successful target trips, incidental catch trips, and unsuccessful target trips; 2) Target trips include successful target trips and unsuccessful target trips; and 3) Catch trips include successful target trips and incidental catch trips. From these are calculated the proportion of successful target trips from all target trips. Catch per unit of effort is calculated from MRFSS data based on corresponding target catch and trips.

Recreational length frequency data for type A (landed whole) catches were obtained from the MRFSS. Supplemental intercept (length) data were provided by Georgia and South Carolina Departments of Natural Resources. However, no length information is available for type B1 and B2 catches.

B. Commercial Catch Data

Landings of Atlantic red drum were obtained from NMFS Headquarters (Virginia and north) and NMFS Southeast Fisheries Science Center (North Carolina and south). Commercial landings in the northern region were principally landed from gillnets (78% for the recent period 1992-1998), haul seines (13% for the same period), and pound nets (6% for the same period). The remaining commercial gears (trawl and commercial lines) landed the remaining 3%. However, no data are available for estimating at-sea discards. Commercial landings in the northern region represented about 34% of total landings with recreational landings representing the remaining 66%. With the slot limit introduced in 1992, there is an increased likelihood of discards at sea because of the minimum and maximum size limits. No comparable value of precision (e.g., PSE) is available for commercial landings.

Commercial landings in the southern region prior to 1988 were principally from Florida and taken with gillnets and lines (69% and 28%, respectively). Recreational landings represented about 95% of the southern region landings for 1986-1987 and essentially 100% since 1988. Commercial landings fluctuated between 54,400 pounds in 1982 to 301,800 pounds in 1998.

Commercial length frequency data were updated by North Carolina Division of Marine Fisheries. Sampling intensity is based on determining landings per 100 fish length samples (C/100n). As a rough reference for sampling adequacy, this value should be less than 200 t per 100 fish sampled. By this standard, adequacy of sampling from the recreational fishery was poor to marginal in 1986, 1988, and 1997 for the northern region and marginal in 1990 and 1994-1995 in the southern region. Sampling in the northern region for gillnet and haul seine was generally adequate, except for 1986 for both gears and 1987 and 1988 for gillnet. Sampling for the other commercial gears were not adequate, but the landings by these other gears was small relative to total landings. Commercial landings in the northern region reached 259,500 in 1981 and continuously declined to >4,000 pounds in 1998.

C. Fishery Independent Data

The North Carolina Division of Marine Fisheries (NC DMF) provided estimates of juvenile (age-0) red drum catch per seine sample for four coastal regions of North Carolina and overall from 1991-1998. The four coastal regions include the northern outer banks, southern outer banks, Pamlico/Neuse Rivers, and White Oak/New Rivers/Alligator Bay. Number of samples ranged from 16-29 per year in the northern outer banks, 18-24 in the southern outer banks, 34-51 in the Pamlico/Neuse Rivers, and 9-30 in White Oak/New Rivers/Alligator Bay.

South Carolina Department of Natural Resources (SC DNR) provided age-specific stratified mean catch per set for red drum with standard errors from trammel net (Wenner, 1999). These data, including standard errors, are based on monthly random net sets between mid-ebb and low tides. Five strata are included, although only two (lower Charleston Harbor and lower Wando River) have been sampled for the entire time period (1991-1998).

A multi-state project funded through MARFIN and using trammel nets as sampling gear provided information on immature red drum in North Carolina, South Carolina, and Georgia which was independent of biases associated with the recreational and/or commercial fisheries. Size and age structure data were used to develop catch curves. These catch curves were then used to estimate selectivity of age 3 to age 2 individuals. Other products of this used in the assessment were age-length keys and catch per unit effort indices (SC). The abbreviated time series of catch data in the MARFIN project limited its' usefulness in the present assessment. However, the sampling methods used in SC and GA were deemed to be sound and, if continued on a long-term basis, will enhance any future Atlantic coast red drum assessments.

Florida Department of Environmental Protection (FL DEP) provided Atlantic red drum indices from the juvenile monitoring program for the northern Indian River (inside Cape Canaveral and south). These indices are based on least-squares means and standard errors from a general linear model that incorporates environmental, temporal, and geographical variables to isolate the year effect. The Florida indices are based on young-of-year (<300 mm SL) and older (300-600 mm SL) fishery independent monitoring (FIM) catch rates. Young-of-year (YOY) index was matched with early age-1 based on our calendar year (about 4 months in age), and FIM was matched with early age 2 and possibly age 3.

III. Analytical Methods and Assumptions

A. Introduction

The 1999/2000 assessment includes tuned virtual population analyses (VPA) that differs from earlier assessments (1990 and 1995) in that the 1990 assessment used catch curves and the 1995 used untuned seperable virtual population analyses. The assessment group determined the FADAPT VPA the most accurate representation of the stock status because it incorporated tuning with fishery independent indexes including the multi-state MARFIN trammel net survey.

B. Age/Growth

Age-length data for the northern region were provided by North Carolina Division of Marine Fisheries (4,214 samples from 1987-1998) and Old Dominion University (via VMRC; 36 samples from 1998). Age-length data for the southern region were provided by South Carolina Department of Natural Resources (35,626 samples from 1985-1998), Georgia Department of Natural Resources (2,837 samples from 1988-1998), and Florida Department of Environmental Protection (866 samples from 1981-1997). These data were used to estimate von Bertalanffy-type growth equations and to develop age-length keys for converting size at age to numbers at age. To convert catch at size based on calendar year to numbers at age also based on calendar year, it is necessary that the age assigned in the development of the age-length key be based on the calendar year. With September 1 used as the theoretical birthdate by the Atlantic coast states, an age 1 fish (January through December of the following calendar year) would range in actual age from 4 months to 16 months. As in Vaughan (1996), growth data are fit to both the single (standard) and linear versions of the von Bertalanffy (1938) growth equations using PROC NLIN in SAS (SAS Institute 1987). The extra parameter of the linear version is significantly different from zero. Thus, the linear version is used in preference to the single von Bertalanffy growth equation in subsequent population models.

C. Maturity

Female maturity schedule is estimated from Ross et al. (1995) and used for both regions. The Assessment Group indicated the maturity schedule needed to be updated and Dr. Wenner with SC DNR was to provide needed information to Dr. Vaughan for future assessments.

D. Mortality

Natural Mortality, Fishing Mortality and Emigration

Natural mortality M is estimated from the relationship to size at age in Boudreau and Dickie (1989). Separate estimates were made of M for subadults (mean of 0.20 for the northern region and 0.23 for the southern region from ages 1-5) and adults (mean of 0.12 for the northern region and 0.13 for the southern region from ages 6 and older).

E. Virtual Population Analysis (VPA)

Assessment Technique Endorsed by Assessment Group

FADAPT VPA.

Restrepo's (1996) FADAPT program, modified from Gavaris (1988), does not require the assumption of separability, and allows for calibration (or tuning) by a series of indices of abundance at age. An estimate of selectivity for the most recent year (1998) is specified based on the separable VPA (SVPA) runs for the late time period.

For the northern region, the NC DMF juvenile abundance index (JAI), and MRFSS-based age-specific catch per unit effort (CPUE) and Pr{success} values are used for tuning. Additional FADAPT runs were made on the early period. Results are summarized in terms of average fishing mortality at age for each period and catch matrix.

For the southern region, the MRFSS-based age-specific CPUE and Pr{success} values, South Carolina Trammel net CPUE and Pr{success}(Wenner, 1999), and Florida YOY and older fishery independent monitoring (FIM) CPUE indices are used for tuning. Results are summarized in terms of average fishing mortality at age for each period and catch matrix.

Other Techniques Applied but Not Endorsed by Assessment Group

Separable Virtual Population Analysis (SVPA).

As in earlier assessments of red drum, SVPA was used to estimate population numbers and fishing mortality at age for the subadults. The separability assumption presumes that fishing mortality at age can be decomposed into year and age components (Doubleday, 1976; Pope and Shepherd, 1982). Thus a fixed selectivity pattern is estimated over the time period to which this approach is applied. For these analyses, we divided the catch at age data (ages 1-5 and years 1986-1998) into two time periods (early: 1986-1991 and late: 1992-1998) during which the management regimes were constant. We dropped 1986-1987 from the early period for the southern region, because of the drastic change in selectivity with the severely reduced commercial fishery after 1987.

The SVPA computer program (Clay, 1990) requires one to specify both a fully-recruited reference age and the relative selectivity of a second age. Ordinarily, the selectivity of the first fully recruited age and the oldest age in the analysis are assumed equal. This was not appropriate for the red drum analyses, because of reduced availability at age 5. For the early time period, the selectivity on age 3 was assumed equal to the selectivity on age 2 (F_3=F_2). For the later period two different assumptions were compared. First, the selectivity on age 3 was assumed equal to that of age 2, as with the early time period. This was probably not a good assumption because a slot limit was imposed by management during 1992-1998; i.e., fish were not allowed to be retained if less than 18" TL or greater than 27" TL for the northern region, and slot of 14" to 27" for the southern region. Florida instituted a slot of 18"-27" with a 1 fish bag limit in late 1987.

Additionally, the slot limit issue was complicated in the northern region because recreationally one fish of a five fish bag limit could exceed the 27" TL. The slot limit issue was also complicated in the southern region with Florida (18"- 27" TL) having a different slot limit than South Carolina and Georgia (14"-27" TL). The regulatory discard of red drum by the commercial fishery (especially in the northern region) were not included in this assessment due to lack of data. Investigation of size distributions at ages 2 and 3 relative to the slot limit suggested that age 3 fish were about 43% legally available relative to age 2 for the northern region and about 87% legally available for the southern region (based on Georgia and South Carolina slot limit. Hence, a second series of SVPA runs were made where the selectivity of age 3 was assumed to be 0.43 times the selectivity of age 2 (F_3=0.43*F_2) for the northern region and the selectivity of age 3 was assumed to be 0.87 times the selectivity of age 2 (F_3=0.87*F_2) for the northern region. These two extremes probably encapsulate a "best estimate" of F from the SVPA approach. Results from the SVPA are summarized in terms of average fishing mortality at age for each period and catch matrix. This approach does not use any auxiliary information (e.g., MRFSS CPUE or fishery independent information), and relies completely on the specification of the catch-at-age matrices and assumptions used to develop them.

<u>Spreadsheet VPA.</u>

From a spreadsheet-based catch-age analysis (Carmichael et al., 1999), a separable, forward projection population model was solved iteratively using the Excel Solver function. This approach permitted the use of auxiliary information.

Analysis of the northern region used catch matrices for 1986-1998 at ages 1-5, with auxiliary information that included the NC DMF juvenile abundance index (JAI) and MRFSS target catch per unit effort (CPUE) as tuning indices. The JAI was used to tune recruitment estimates for 1992-1998, with 1997 omitted as an outlier (it is suspected that hurricanes contributed to the low 1997 JAI value), while the CPUE is used to tune the total annual abundance from 1987 to 1998. The model estimated 40 parameters from 96 data points by minimizing an objective function that incorporates lognormal errors in predicted catch at age, JAI, and CPUE values. Two selectivity periods (1986-1991 and 1992-1998) were used to account for regulatory changes in the fishery, and selectivity for ages 2 and 3 are fixed at the same values used in the SVPA assessment runs ($F_3 = F_2$ for early and F_3=0.43*F_2 for later). Results are summarized in terms of average fishing mortality at age for each period and catch matrix. Analysis of the southern region used catch matrices for 1988-1998 at ages

1-5, with auxiliary information that included the MRFSS targeted CPUE and South Carolina trammel net survey catch at ages 1-5 as tuning indices. The CPUE was used to tune total abundance estimates for 1986-1998, while the South Carolina survey was used to tune annual abundance at age from 1992 to 1998. The model estimated 36 parameters on the log scale from 101 data points by minimizing an objective function that incorporates lognormal errors in predicted catch at age, South Carolina abundance survey, and CPUE values. Two selectivity periods (1988-1991 and 1987-1992) were used to account for regulatory changes in the fishery, and selectivity for ages 2 and 3 are fixed at 1.00. Age-1 selectivity was fixed at 0.2 for the early period and 0.15 for the late period. These values were the best estimates as based on initial model runs and further supported by sensitivity analysis. Results are summarized in terms of average fishing mortality at age for each period and catch matrix.

F. Recruitment

In the northern region, recruitment has fluctuated with no trend ranging from 550,000 recruits to age 1 in 1991 to 75,000 in 1998. In the southern zone recruitment has shown a steady decline with a high of 1.2 million recruits in 1987 to 200,000 in 1998.

G. Escapement and Spawning Potential Ratio (SPR) (Maximum Spawning Potential)

Estimates of escapement to age 4 and static SPR (%MSP in Gabriel et al., 1989) are summarized by VPA approach, catch-at-age matrix (assumption on B2), temporal period (early vs late), and where appropriate assumption on selectivity of age 3 relative to age 2. Because of concerns about retrospective error, values for 1998 were not included in the period averaging. Escapement and static SPR estimates are summarized separately by region. Escapement and static SPR were found to be generally low during the early period (1986-1991 for northern region and 1988-1991 for southern region), and higher in the later period (1992-1997) for all catch matrices, VPA approaches, and regions. Hence, the management actions taken for Atlantic red drum effective with the 1992 fishing year were successful to the extent that they led to a discernable improvement in escapement and static SPR values found for the Atlantic red drum stock compared with very low levels during the early period.

In general, estimates of escapement and static SPR are lower for VPAs based on the DELTA and PROP catch matrices compared to the BASE0 and BASE1 catch matrices. Recall that the BASE0 catch matrix assumes no release mortality for the recreational fishery, and the BASE1 catch matrix assumes that the size of the released red drum from the recreational fishery are the same as the retained. Both of these assumptions are likely wrong. The DELTA catch matrix attempts to estimate the size of the released recreational red drum for the late period from the difference in size frequency noted between the two time periods. The PROP is intermediary between the DELTA catch matrix and BASE1 catch matrix for the late period. Hence, the DELTA or PROP catch matrices probably provides the more realistic treatment for use as catch matrices in a VPA.

For the SVPA on the northern region catch matrices, when the reduced selectivity on age 3 was set to 0.43 times the selectivity of age 2 based on size distribution of these ages within the slot limit, considerably larger values of escapement and static SPR were found compared to the assumption of equal selectivity between ages 2 and 3. Because the management regime were not a true slot limit (allowing 1 fish over the slot recreationally) and no data was available for commercial regulatory discards, these estimates of escapement and static SPR based on the reduced selectivity of age 3 relative to age 2are likely biased high. Hence, escapement and static SPR values are probably well above those based on identical selectivity, but not quite as high as those using 43% selectivity of age 3 relative to age 2. Because the difference in selectivity assumption is narrower when using SVPA for the southern region catch matrices (87% versus 100%), the difference in estimates of escapement and static SPR are also more similar.

For the northern region, the Spreadsheet VPA approach suggested generally higher escapement and static SPR values than the FADAPT VPA approach, especially for those based on the DELTA and PROP catch matrices. For the southern region, there was much less discrepancy between these VPA approaches for the DELTA and PROP catch matrices, although the discrepancy remained for the BASE0 and BASE1 catch matrices. Note that the FADAPT calibration method is less constrained than the Spreadsheet VPA method, especially with respect to any separability restraint.

The sensitivity of FADAPT to the assumption of selectivity was investigated. In general, the greater the selectivity of age 3 relative to age 2, the smaller the resultant estimates of escapement and static SPR. In particular, northern region estimates of escapement and static SPR based on the DELTA matrix declined with increasing selectivity of age 3 relative to age 2. Similarly, southern region estimates of escapement and static SPR based on the DELTA matrix declined with increasing selectivity of age 3 relative to age 2. The average in catch between age 3 relative to age 2 from MARFIN (Trammel Net) compared to the MRFSS was estimated from data from Georgia (0.95 for MARFIN compared to 2.05 from MRFSS from Table 3, Woodward et al., 1999) and from South Carolina (1.04 from MARFIN compared to 2.08 from MRFSS from Table 14 in Wenner, 1999). Surprisingly, MARFIN data from North Carolina (Paramore, 1999) suggested a greater slope (higher Z) than the MRFSS data (2.30 from MARFIN compared to 1.29 for MRFSS). This difference may be, in part, due to the general availability of the older, larger red drum to the recreational fishery in North Carolina in its large bays and sounds as compared to states to the south. The usefulness of these data to pinpoint what the relative selectivity of age 3 to age 2 is unclear.

IV. Status of Stock and Recommendations

Best estimates of static SPR and escapement were obtained from specific selectivity assumptions based on the Red Drum Assessment Group recommendations. The selectivity of age 3 relative to age 2 assumed for the northern region was 0.7 and for the southern region was 0.87. The Atlantic coast red drum stock is overfished with best estimates of SPR to be 18% (15% and 20%) for the northern region and 15% for the southern region. In addition escapement is estimated at 18% for the northern region and 17% for the southern region. The estimate in the northern region was considered by the Assessment Group to be an overestimate because the additional unaccounted discard mortality from net fisheries.

No estimates are available for red drum spawning stock biomass however, the Group feels the incorporation of the trammel net survey provides a more accurate estimate of escapement rate and recruitment. Recruitment has seriously declined in the southern region.

Federal waters remain closed and no recommendation for change was considered given the continued low escapement rate and spawning potential ratios. Most states have implemented regulations (Table 1) which meet the initial ASMFC escapement goal of 10% but the stock remains overfished (<30% SPR) and below the Council's long-term optimum yield of 40%SPR. The group emphasized that North Carolina recently adopted more stringent regulations which are not reflected in this assessment. Those regulations are expected to significantly benefit the stock however no estimate of anticipated escapement or SPR associated with those regulations have been developed. Further analyses on state regulations necessary to achieve target escapement and long-term SPR are expected to be accomplished by NMFS later this year. In addition, the group endorsed holding a workshop in the fall on red drum research and assessment techniques.

VI. Current Regulations

Atlantic coast Federal waters remain closed to harvest or possession of red drum. ASMFC Amendment 1 designated a series of steps to achieve the target SPR level of 30 percent. Currently, the South Atlantic Board has determined that the states must adopt the management measures that will attain an SPR level above 10 percent (first step of phase-in approach). The 10 percent scenario requires states to adopt either of two options: 1) 18-inch Total Length (TL) minimum, 27-inch TL maximum, and a 5 fish bag limit with one fish exceeding 27-inch TL; or 14-inch TL minimum, 27-inch maximum, and 5 fish bag limit, with no fish exceeding 27-inches TL.

Table 1. Atlantic coast red drum regulations.

State	Size Limit (TL inches)	Possession Limit	Other	Meets ASMFC FMP requirement?
ME	None	None	None	N/A
NH	18" min.; 27" max.	None	0 fish < 27" TL	N/A
MA	14" minimum	None	None	N/A

CT	None	None	0 fish < 32" TL	N/A
RI	None	None	None	N/A
NY	14" minimum	None	2 fish > 32" TL	N/A
NJ	18" min.; 27" max.	None	1 fish > 27" TL	Yes
PA	None	None	None	No
DE	18" min.; 27" max.	5 fish	1 fish > 27" TL	Yes
MD	18" min.; 27" max.	5 fish	1 fish > 27" TL	Yes
PRFC	18" min.; 27" max.	5 fish	1 fish > 27" TL	Yes
VA	18" min.	5 fish	1 fish > 27" TL	Yes
NC	18" min.; 27" max.	1 fish	0 fish > 27" TL; Commercial quota = 250,000 lbs.; daily trip limit of 100 lbs.; attend gill nets < 5" stretch mesh from May 1 - Oct. 31	Yes
SC	14" min.; 27" max.	5 fish	Gamefish - no sale	Yes
GA	14" min.; 27" max.	5 fish	0 fish > 27" TL	Yes
FL	18" min.; 27" max.	1 fish	Gamefish - no sale	Yes

V. Essential Fish Habitat and Essential Fish Habitat - Habitat Areas of Particular Concern

The review group discussed the Councils designation of Essential Fish Habitat and Essential

Fish Habitat-Habitat Areas of Particular Concern and indicated protection of these habitats is extremely important to maintaining a healthy red drum population. It was noted that protection of the upper estuarine habitats where larval and juvenile red drum settle, is especially at risk considering the rapid growth of the South Atlantic coastal zone.

For red drum, essential fish habitat (SAFMC, 1998a; 1998b) includes all the following habitats to a depth of 50 meters offshore: tidal freshwater; estuarine emergent vegetated wetlands (flooded saltmarshes, brackish marsh, and tidal creeks); estuarine scrub/shrub (mangrove fringe); submerged rooted vascular plants (sea grasses); oyster reefs and shell banks; unconsolidated bottom (soft sediments); ocean high salinity surf zones; and artificial reefs. The area covered includes Virginia through the Florida Keys.

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for red drum (SAFMC, 1998a; 1998b) include all coastal inlets, all state-designated nursery habitats of particular importance to red drum (for example, in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas); documented sites of spawning aggregations in North Carolina, South Carolina, Georgia, and Florida described in the Habitat Plan; other spawning areas identified in the future; and habitats identified for submerged aquatic vegetation.

VI. Research Needs

The Assessment Group identified lists of research needs exist in the SAFMC operations plan and Habitat Plan as well as in the ASMFC research needs document. The Group endorsed the research recommendations contained in the stock assessment report until further review and refinement of these needs into proposals for realistic long-term programs was accomplished by the Group later this year. The first step taken by the Group in refinement of research needs was the development of a draft list of prioritized Atlantic Coast Red Drum Research needs which is included in Attachment 1.

Research needs listed in the stock assessment are as follows:

Primary needs for future stock assessments include continued and improved collection of the following data sets: 1) Catch statistics (sampling of at-sea discards is a major data gap), 2) length frequency distributions by gear (major need described below), and 3) age-length keys. It is important to continue to improve the number of MRFSS intercepts, because recreational landings represent over 90% of total landings by number coastwide, over 99% in the southern region, and even 66% in the northern region.

There is a need for information on at-sea discards from the commercial fishery primarily in the northern region, both amount of discard and size information. In addition, there is a need for size information on recreational discards (B2 fish) for both regions. Information is needed to better understand the relative selectivity of ages, because this has been a major stumbling block in assessing this stock. This is related in part to the use of slot limits used in management and migration patterns of the stocks.

Parameters for population models still require better estimates of natural mortality rates (subadult M_1 and adult M_2), to which VPA results can be quite sensitive.

Estimates of fecundity as a function of Atlantic red drum length or weight would prove useful, although it does not appear to be unreasonable to assume a similar relationship as red drum from the Gulf of Mexico. As used in this and earlier stock assessments, it is not necessary that the absolute value of the estimates be correct, but that the rate of increase in egg production with female age be similar.

Continued standardized sampling of subadults (ages 1-5) is also needed to develop long-term indices of recruitment. This is necessary to permit short-term warning of potential recruitment failure. The evidence of such failures typically appears in the catch or other fishery statistics too late for management action to be effective. Furthermore, fishery independent indices are highly desirable as indices of abundance for use in tuning approaches to VPA (Pope and Shepherd, 1985; National Research Council, 1998). These methods require one or more indices of abundance, and permit greater confidence in the more recent estimates of fishing mortality rates (and population size). In particular, these methods may increase our confidence in the detection of a decline in fishing mortality rates in the most recent years since management actions have taken place.

Monitoring of adult red drum is needed to provide a fishery independent index of spawning stock (e.g., possibly by aerial counting of schools as in the Gulf of Mexico). Conceptually, the application of a VPA to the entire age structure (i.e., through age 50 or 55) is not practical. There are too many ages with relatively small growth from ages 6 through 55, thus an age-length key is not likely to be useful in assigning age to fish sizes. Furthermore, too few red drum of these ages are caught for application of VPA techniques.

Stock status is often assessed from two perspectives. What is the current level of the spawning stock biomass, and are fish being removed at too great a rate? There are currently no data available from which to estimate present levels of adult or spawning stock biomass. Hence, this report addresses the second perspective, but not the first. The population models used in this assessment (specifically escapement and percent maximum spawning potential) are based on equilibrium assumptions, so that the model results in this report are only valid in assessing long-term effects based on current removal (fishing) rates.

However, two data sets allow a very crude look at adult abundance. Age frequency distributions of North Carolina aging data are compared for several time periods. Data for 1969-1971 were provided by William Foster (unpublished data), while data for two later time periods (1986-1991 and 1992-1998) were provided by North Carolina Division of Marine Fisheries (NC DMF). These data suggest a greater proportion of older fish were available during 1969-1971 than more recently. Citation data, number of fish exceeding a specified size, have been made available by NC DMF and Virginia Marine Resources Commission (VMRC). The citation data also suggest that older red drum were more available both in the late 1960s (VMRC data only) and late 1990s, with lower availability in the interim. However, there have been many qualitative changes to the collection of this information which can obscure or confound any conclusions that might be drawn from them over longer time periods.

Any rebuilding schedule must take into account the generation time of red drum. Maximum age of red drum from the North Carolina aging data was 62 years with several in their early to mid 50s. And yet the onset of sexual maturity is significant with age 3 females. Because Atlantic red drum are both long-lived and mature relatively young, the generation time is on the order of 15-20 years, calculated from the mean age at reproduction of a cohort of females in the unfished stock (i.e., mean age of mature females weighted by age-specific egg production when F=0) (Charlesworth, 1980).

There is no current estimate of present levels of the adult red drum stocks. Because the development of a rebuilding schedule assumes that information is available as to the current level of the adult stock, no rebuilding schedule can presently be developed for red drum.

VII. Stock Assessment Group Members

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Attachment 1. List of Prioritized Red Drum Research Needs.

Red Drum Research Needs – Draft Updated April 2000

1. Develop a survey design for fishery-independent sampling of sub-adult and adult red drum in each state from North Carolina to Florida. The purpose of this survey would be to: 1) verify escapement to the spawning population; 2) provide an index of recruitment to age 1; and 3) provide an estimate of the biomass of adult red drum.

2. Determine habitat preferences, environmental conditions, growth rates, and food habits of larval and juvenile red drum throughout the species range along the Atlantic coast. Assess the effects of environmental factors on stock density.

3. Identify spawning areas of red drum in each state from North Carolina to Florida so these areas may be protected from degradation and/or destruction. Determine the impacts of dredging and beach re-nourishment on red drum spawning and early life history stages.

4. Continue tagging studies to determine stock identity, inshore/offshore migration patterns and mortality estimation.

5. Determine the survival rate of red drum following regulatory and voluntary discard from commercial and recreational gear, including recreational net fisheries. Evaluate effects of water temperature and depth of capture.

6. Improve catch/effort estimates and biological sampling from recreational and commercial fisheries for red drum, including increased efforts to intercept night-time fisheries for red drum by the NMFS MRFSS. Characterize magnitude of commercial and recreational discards.

7. Investigate and evaluate new stock assessment techniques as alternatives to age-structured models. Conduct yield modeling on red drum.

8. Investigate the concept of estuarine reserves to increase the escapement rate of red drum along the Atlantic coast.

9. Fully evaluate the efficacy of using cultured red drum to restore native stocks along the Atlantic coast, including cost-benefit analyses.

10. Identify the effects of water quality degradation on the survival of red drum eggs, post-larvae, larvae, and juveniles.

11. Refine maturity schedules on a geographic basis, determine relationships between annual egg production over a range of sizes, ages and across latitude.

Additional Low Priority Research Needs

Develop a more reliable estimate of natural and fishing mortality through directed sampling of the adult population.

Examine the effectiveness of controlling fishing mortality and minimum size in managing red drum fisheries.

Quantify relationships between red drum production and habitat.

Determine methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production.

Document and characterize schooling behavior for Atlantic coast red drum.